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## FERRITIC-AUSTENITIC STAINLESS STEEL

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Abstract not available for JP56051222B

Abstract of corresponding document: **US3736131**

An austenitic-ferritic stainless steel consisting essentially of up to about 0.06 percent carbon, about 4.0 to less than 11.0 percent manganese, about 19 to about 24 percent chromium, about 0.12 to about 0.26 percent nitrogen, nickel up to about 3.0 percent, and remainder substantially iron except for incidental impurities. The austenite-ferrite balance, ranging between 10 percent and 50 percent austenite, is stable and the steel exhibits high toughness, corrosion resistance and excellent weldability.

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Description of corresponding document: **US3736131**

### BACKGROUND OF THE INVENTION

#### 1. Field of the Invention

This invention relates to a modified chromium stainless steel (low in nickel, copper and cobalt) of stable ferritic-austenitic structure having excellent toughness, ductility, corrosion resistance and welding characteristics. The alloy of the invention, by reason of its compositional balance, achieves a structure of from 10 percent to 50 percent austenite (preferably 20 percent to 30 percent) in a ferritic matrix which resists transformation into martensite despite cold working, heat treatment, or welding.

The stainless steel of this invention has particular utility as weldments in straight chromium steels, for fabrication into fasteners which require cold heading, and a variety of other applications requiring relatively high strength and ductility, good weldability, and high resistance to intergranular corrosion in

strongly oxidizing media, as well as good resistance to stress corrosion in chloride media.

## 2. Description of the Prior Art

Among the numerous alloys developed to offset the scarcity and high cost of nickel are those disclosed : U.S. Pat. No. 2,778,731 issued Jan. 22, 1957, to D. Carney, consisting of 0.06 percent to 0.15 percent carbon, 14 percent to 20 percent manganese, 17 percent to 18.5 percent chromium, 0.05 percent to 1.0 percent nickel, 0.25 percent to 1.0 percent silicon, 0.25 percent to 1.0 percent nitrogen, and remainder iron; B & W CROLOY 299 consisting of 0.20 percent carbon, 15.0 percent manganese, 17.0 percent chromium, 1.5 percent nickel, 0.35 percent nitrogen, and remainder iron; and other fully austenitic steels such as Armco 16-16-1 and Allegheny Ludlum 205.

A fully austenitic stainless steel having excellent physical properties and stress corrosion resistance at cryogenic temperatures, coupled with great tensile strength when drastically cold reduced, is described in copending application Ser. No. 868,893 filed Oct. 23, 1969, in the name of George N. Goller and Ronald H. Espy. This steel is non-magnetic.

Straight chromium stainless steels such as A.I.S.I. Types 430, 442 and 446 have the serious disadvantage of being brittle and subject to corrosion in the heat affected zone of the base metal of a weldment. Further, the unaffected base metal may be low in impact strength at room temperature.

Typical of austenitic stainless steels which transform with cold working to less ductile martensite is A.I.S.I. Type 304, consisting of 0.08 percent maximum carbon, 2.0 percent maximum manganese, 18 percent to 20 percent chromium, 8 percent to 10.50 percent nickel and balance iron.

An alloy developed for cold heading applications which does not transform to martensite is designated as IN 744X. This steel contains about 26 percent chromium and is about half austenitic and half ferritic. Due to the high alloy content the cost is excessively high.

## SUMMARY OF THE INVENTION

The principal object of this invention is to provide a magnetic austenitic-ferritic stainless steel essentially consisting of chromium, manganese, carbon and nitrogen which is stable against transformation to martensite regardless of cold working, heat treatment or welding, which has good ductility, toughness and corrosion resistance in its as-welded condition, and high strength, but which nevertheless is relatively low in cost because of lower alloy content than prior art alloys offered for applications requiring the above properties.

According to the invention a stainless steel having a two-phase structure comprising between 10 percent and 50 percent austenite in a ferrite matrix consists essentially of from about 4.0 percent to less than 11.1 percent manganese, about 19 percent to about 24 percent chromium, and about 0.12 percent to about 0.2 percent nitrogen. Carbon is of course present and is limited to a maximum of about 0.06 percent. Phosphorus and sulfur, normally present as impurities, are limited to a maximum of about 0.03 percent each. Silicon is also normally present, in amounts up to 1.0 percent maximum. Nickel may be present, ranging from trace amounts up to about 3.0 percent. Copper and cobalt, if present as residual elements, are limited to a maximum of about 0.5 percent each. The balance is of course iron, together with incidental impurities.

Molybdenum may be substituted for chromium on a 1:1 basis in amounts up to about 5 percent for improved resistance to corrosion in pitting media.

Columbium may be added in amounts up to about 1 percent for improved weld area corrosion resistance.

The austenite level, preferably 20 percent to 30 percent, is achieved through addition of nitrogen (a strong austenite former) within the range of 0.12 percent and 0.26 percent. Carbon, although maintained at a low level, also contributes to some extent to austenite formation. The austenite is maintained at a stable level by reason of the chromium, manganese and nitrogen relationship. It is thus apparent that the composition balance among the essential elements is in every sense critical. Unlike prior art austenitic-ferritic alloys, nickel, copper and cobalt contents are maintained at low levels, and hence the steel of the invention is not subject to stress corrosion failure when exposed to hot chloride media. The use of manganese to stabilize the austenite balance results in a ductile material which is also resistant to stress cracking in hot chloride media. The low carbon content tends to prevent intergranular corrosion when welded.

At least about 0.12 percent nitrogen is necessary in order to form sufficient austenite. Nitrogen in excess of about 0.26 percent would exceed the solubility limit of this element and hence would result in porosity and unsoundness in the metal.

A minimum of about 4 percent manganese is required in order to balance the chromium and thereby stabilize the austenite. Excessive manganese adversely affects the balance with chromium, increasing the austenite level above the desired range, and the maximum manganese content is thus less than 11.0 percent.

Nickel, if present, is limited to a maximum of about 3.0 percent. It has been found that the stress corrosion resistance of the metal will be adversely affected if the nickel content exceeds 3.0 percent. Within the prescribed range, nickel will of course increase the austenite level and thus cooperates with the nitrogen in this function, without adversely affecting toughness.

## PREFERRED EMBODIMENTS OF THE INVENTION

While, as indicated above, in its broad ranges the steel of the invention consists essentially of carbon up to about 0.06 percent, manganese about 4.0 percent to less than 11.0 percent, chromium about 19 percent to about 24 percent, nitrogen about 0.12 percent to about 0.26 percent, nickel up to about 3.0 percent, phosphorus and sulfur up to about 0.03 percent each, silicon up to about 1.0 percent, copper and cobalt up to about 0.5 percent each, and remainder substantially iron, a preferred composition comprises about 0.06 percent carbon, about 6.0 percent manganese, phosphorus and sulfur low, about 0.40 percent silicon, about 21.0 percent chromium, about 0.20 percent nickel, about 0.20 percent nitrogen, copper and cobalt low, and balance substantially iron.

A series of heats was prepared in order to establish parameters for the composition which would achieve the novel combination of properties. The compositions of these heats are set forth in Table I below. Heats designated as B, E, H, I, J, K, L, P and Q are steels of the invention. ##SPC1##

Table II below summarizes the effect of the austenite percentage level on the hardness and toughness of the heats of Table I both in the annealed and austenitized condition. In Table II the heats are listed in the order of increasing austenite content. Heats L, I, B, J and K fall within the preferred austenite levels of 20 percent to 30 percent, and heats I and B have optimum properties. ##SPC2##

A Charpy V notch impact strength of 2 kgm/cm@2 in the annealed condition is considered the minimum acceptable toughness.

The austenite percentage was measured on a calibrated permanent magnet gauge known as a MAGNE-

GAGE.

The data of Table II indicate that for nitrogen contents over about 0.20 percent, an average of at least 20 percent austenite is needed to impart good toughness. With nitrogen contents less than about 0.20 percent, a minimum average austenite level of 10 percent is sufficient to impart satisfactory toughness.

Tables III through VIII below list certain selected heats and compare the effect on hardness and toughness of variation of chromium, manganese, nitrogen, carbon, nickel, and chromium plus nickel, respectively, other elements in each Table being substantially constant.

The data on hardness are included to show transformation to martensite. High hardness indicates that transformation to martensite has occurred. The magnetism values measure both ferrite and martensite since both are magnetic, but if the hardness does not increase after annealing or austenitizing, substantially all the magnetic phase remains as ferrite. ##SPC3##

From Table III it will be noted that with all other elements substantially constant, chromium contents of less than about 19 percent permit the austenite to transform to martensite, thereby increasing the hardness and reducing the impact strength. Chromium contents greater than about 24 percent decrease the quantity of austenite and the impact toughness.

Table IV indicates that with all other elements substantially constant manganese contents of less than about 4 percent result in a transformation of austenite to ferrite.

Table V shows the effect of nitrogen in control of the austenite-ferrite balance. Nitrogen contents of less than about 0.12 percent, with all other elements substantially constant, result in too low an austenite content to provide good toughness.

The effect of carbon in control of the austenite-ferrite balance is shown in Table VI. With all other elements substantially constant, carbon contents within the range of 0.013 percent to 0.055 percent increase the austenite content but have little effect on toughness.

Table VII shows the effect of nickel in control of the austenite-ferrite balance. With all other elements substantially constant, nickel contents in the range of 0.14 percent to 5.1 percent increase the austenite from about 20 percent to about 90 percent with good toughness over the entire range.

The effect on toughness of varying the chromium and nickel contents while maintaining a constant austenite level is shown in Table VIII. With all other elements substantially constant, a chromium content of just over 24 percent with 1.2 percent nickel cause a significant decrease in toughness.

Mechanical properties of the steels of the invention are set forth in Table IX below. ##SPC4##

Weld area corrosion tests were conducted on samples of Heat B, a preferred composition of the invention with the following results:

<tb> CuSo4 65% Boiling Boiling

<tb> MgCl2

<tb> A 393 HNO3 240 Hours

<tb> Ann. Aus. Ann. Aus. Ann. Aus.

<tb> No corro-

<tb> No corro- .0020 IPM

<tb> .0014 IPM No No

<tb> sion sion No accel.

<tb> No. accel. Cracks Cracks

<tb> corr. corr.

The boiling HNO<sub>3</sub> tests comprised 3 48-hour periods.

From the above data it is apparent that there is provided a stainless steel which, by reason of its composition and critical balance of essential elements, achieves the objectives hereinbefore stated.

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Claims of corresponding document: **US3736131**

The embodiments of the invention in which an exclusive property or

1. A stainless steel having a two-phase structure comprising between 10 percent and 50 percent austenite in a ferrite matrix, consisting essentially of up to about 0.06 percent carbon, about 4.0 percent to less than 11.0 percent manganese, about 19 percent to about 24 percent chromium, about 0.12 percent to about 0.20 percent nitrogen, nickel up to about 3.0 percent, phosphorus and sulfur up to about 0.03 percent each, silicon up to about 1.0 percent, copper and cobalt up to about 0.5 percent

2. The stainless steel of claim 1, containing about 0.02 percent carbon, about 6.0 percent manganese, about 19.0 percent to about 21.0 percent chromium, about 0.20 percent nitrogen, about 0.20 percent nickel, and about 0.40 percent

3. The stainless steel of claim 1, wherein carbon is present in an amount

4. The stainless steel of claim 1, wherein manganese is present in the

5. The stainless steel of claim 1, wherein chromium is present in the

6. The stainless steel of claim 1, wherein nitrogen is present in the

7. The stainless steel of claim 1, wherein nickel is present in the amount

8. The stainless steel of claim 1, wherein molybdenum is substituted for

9. The stainless steel of claim 1, including columbium in amounts up to

10. A stainless steel having a two-phase structure comprising between 20 percent and 30 percent austenite in a ferrite matrix, consisting essentially of about 0.02 percent carbon, about 6.0 percent manganese, about 19.0 percent to about 21.0 percent chromium, about 0.20 percent nitrogen, about 0.20 percent nickel, phosphorus and sulfur up to about 0.03 percent each, silicon up to about 0.40 percent

11. Welded articles having a two-phase structure comprising between 10 percent and 50 percent austenite in a ferrite matrix, consisting essentially of up to about 0.06 percent carbon, about 4.0 percent to less than 11.0 percent manganese, about 19 percent to about 24 percent chromium, about 0.12 percent to about 0.20 percent nitrogen, nickel up to about 3.0 percent, phosphorus and sulfur up to about 0.03 percent each, silicon up to about 1.0 percent, copper and cobalt up to about 0.5 percent

12. Cold headed fasteners having a two-phase structure comprising between 10 percent and 50 percent

austenite in a ferrite matrix, consisting essentially of up to about 0.06 percent carbon, about 4.0 percent less than 11.0 percent manganese, about 19 percent to about 24 percent chromium, about 0.12 percent to about 0.26 percent nitrogen, nickel up to about 3.0 percent, phosphorus and sulfur up to about 0.03 percent each, silicon up to about 1.0 percent, copper and cobalt up to about 0.5 percent each, and remainder substantially iron.

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